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Case study: Wear analysis of the middle plate of a heavy-load scraper conveyor chute under a range of operating conditions

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ABSTRACT

The wear characteristics and related mechanisms of the middle plate of a coal conveyor chute were investigated. Multiple sets of wear tests were performed in order to simulate the range in working conditions of the super heavy-load scraper conveyor. Three compositions of mixed material (coal, gangue and water) were tested at different contact pressures and sliding speeds. The results indicate that the wear loss of the middle plate increases with the contact pressure and sliding speed with the same composition mixed material. In addition, the wear loss shows a decreasing trend with an increase in the mass ratio of water, coal and gangue at a specific contact pressure and sliding speed. Based on the substantial analysis of experimental data, interaction technique, modern tribology theory, and the appearance of the samples after the experiment, a statistical wear mechanism distribution diagram of the middle plate was constructed. This diagram is divided into three regions: a slight wear region, a moderate wear region and a severe wear region. The dominant wear mechanism was verified with the observed wear morphology of the middle plate after a given length of time. Therefore, this approach is proposed to be valid and practical. They provide a reliable theoretical basis and technical support for the design, use, and maintenance of the middle plate, the chute, and the entire scraper conveyor.

1. Introduction

Coal has always been an important foundational energy and industrial raw material in the world, and it supports sustained and rapid development of the economy and society. High efficient exploitation and rational utilization of coal are very significant events for the energy industry in the world [1]. Fully mechanized coal mining technology that integrates support, mining, loading, transportation and more is an important mining technology in coal mines [2,3]. Scraper conveyors mainly consisting of a motor, hydraulic coupling, reducer, shaft coupling, sprocket, scraper, ring chain and multi section chute are key devices to ensure the effective implementation of transport links in fully mechanized coal mining technology, and a diagram of the structure composition is shown in Fig. 1. The scraper conveyor undertakes arduous tasks, including transporting coal, providing a running track for shearer and pushing the fulcrum for hydraulic support. In recent years, with the continuous expansion of the scale of coal mining, the use of a super heavy-load scraper conveyor has become increasingly widespread.

The chute is the key part of a super heavy-load scraper conveyor, and it mainly consists of a middle plate, bottom plate, groove, running mechanism and blocking coal board. The structure composition of a single section chute is shown in Fig. 2. The weight of all chutes accounts for 80% of the entire scraper conveyor [4]. Failure of the chute will inevitably lead to failure of the entire scraper conveyor and cause an accident [5–8]. The main reason for chute failure is wear, and the most severe wear, with a short service life, of the chute compositions occurs on the middle plate. Therefore, it is urgent to perform research on wear testing and wear theory of the middle plate.

During the sliding process of middle plate and mixed material, wear plays an important role in the formation and development of chute damage. The wear types and its influencing factors of chute were studied by means of tribological system analysis method [9]. In view of the failure phenomenon of the middle plate, the wear characteristics and the cause of the failure are analyzed through the friction principle [10]. The tribological parameters variation law of friction pair between middle plate and high-strength circular chain is fully studied [11]. The influences of curve radius, worn wheel and rail profiles, coefficient of friction on the wheel/rail life have been studied in order to find the behaviour of the different models [12]. The dependence of wear volume on normal load and also on adhesion arising out of surface forces was studied [13]. Wear rates were seen to

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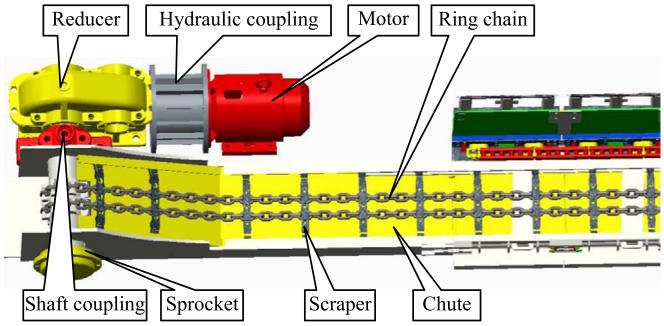

Fig. 1. Diagram of the structure composition of a scraper conveyor.

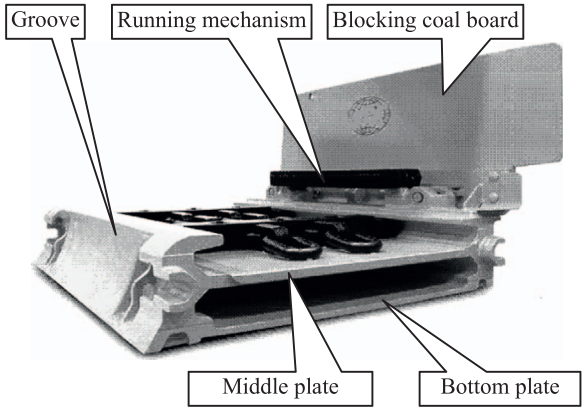

Fig. 2. Schematic diagram of the structure composition of a single section chute.

increase steadily initially and then to level off, before increasing rapidly as the severity of the contact conditions increased [14]. Some papers above on the chute are mainly focused on the study of wear types and influencing factors, and are not focused on the wear behavior and wear mechanism. Other papers studies had some research on the wear behavior, but in which the working conditions and tribological pair properties were different from the object of this study, that can not fully guide this study. In addition, there is a lack of wear test between the middle plate and the mixed material, so the study on the wear characteristics and mechanism of middle plate in the consideration of the working condition and the environmental condition is not enough.

In this study, the wear characteristics and mechanisms of the middle plate of chute were evaluated according to a comprehensive analysis of both test data from a series of wear tests and a wear mechanism distribution diagram. On the basis of this study, a new wear regularity theory of the middle plate of chute was obtained.

2. Experimental details

2.1. Test equipment and specimens

To obtain accurate and practical test results, the research work was performed using MLS-225 wet sand semi-free wear tester, as shown in Fig. 3, and the wear tester can accurately simulate the actual operating conditions and influence factors of the super heavy-load scraper conveyor chute. The rubber wheel inside the wear tester drives mixed material to perform the dynamic wear with a middle plate specimen, and the control system of the wear tester realizes the changes with different contact pressures and sliding speeds. The specimen wear loss was measured by electronic analysis balance.

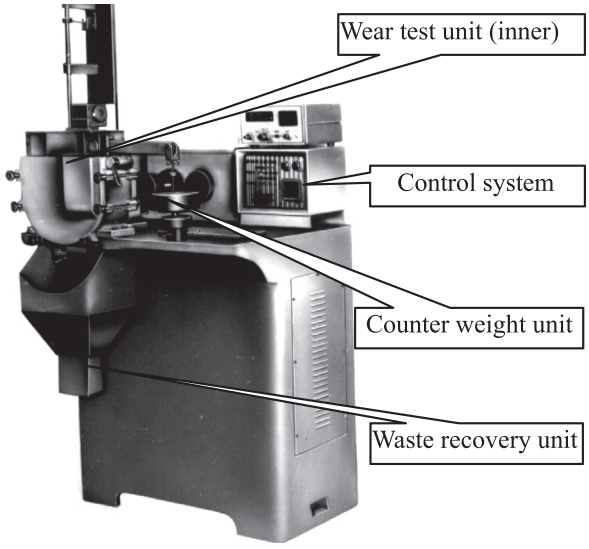

Fig. 3. MLS-225 wear tester.

According to the size of the specimen holder of the wear tester, the middle plate of material NM400 was first cut and then refined to a standard size. The standard size (length × width × height, mm) is 57 × 25.5 × 6, as shown in Fig. 4. The NM400 plate of which carbon content is 4–5%, the chromium content is 25–30%, and Brinell Hardness (HB) value is about 400, is high strength and corrosion resistant material. In addition, the processing performance of NM400 plate is good that can be cut, bended and welded easily.

Considering the contact situation between the middle plate and mixed material, the coal, gangue and water were chosen as compositions for the mixed material. In the work environment of the middle plate where the Relative Humidity(RH)changes from 10% to 90%, in addition due to the existence of local water seepage in the coal mine, the water content in mixed materials is great. To accurately and comprehensively obtain the test results, A, B, and C, three material types with adding schemes, were designed. Each scheme had six copies, and the specific mixed material composition is shown in Table 1.

2.2. Experimental condition

According to the Chinese standard MT/T 105-2006 “General specification for scraper conveyor”, a scraper conveyor with power greater than 450 kW is a heavy scraper conveyor. In this study, the scraper conveyor model is SGB1200/4500 and the power is 4500 kW, which belongs to the super heavy-load scraper conveyor. The scraper conveyor is used in Baode coal mine 3-3 fully mechanized working face, and its basic performance parameters are shown in Table 2. In the actual work, the scraper conveyor is generally used in the form of sub-class, each class continuous 8 h working time.

Considering the actual operation condition of scraper conveyor, the values of contact pressure and sliding and sliding speed are designed as shown in Table 3. The conversion of different contact pressures and sliding speeds was realized by adjusting the control system of the wear tester. To better study the wear characteristics of the plate, reduce the error caused by randomness and ensure the accuracy and credibility, all mixed material composition ratios (water: coal: gangue), contact pressures and sliding speeds were respectively combined to carry out a total of 48 groups of tests. Each group test lasted 8 h, and the test data test was recorded at the same time.